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(54) Title: EXPRESSION OF DNA SEQUENCES DERIVED FROM NOCARDIOFORM MICROORGANISMS (57) Abstract A cloning vector contains a DNA sequence derived from a Nocardioform microorganism, and is capable of expressing the DNA sequence in a host microorganism. Recombinant cholesterol oxidase is produced by a host microbial cell transformed with a cloning vector containing cholesterol oxidase encoding DNA derived from a Nocardioform microorganism. A method for determining cholesterol oxidase in a sample of fluid from a human includes contacting the sample with the Nocardioform microorganism derived recombinant cholesterol oxidase.		

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EXPRESSION OF DNA SEQUENCES DERIVED
FROM NOCARDIOFORM MICROORGANISMS

Background of the Invention

This invention relates to gene expression.

5 The organisms grouped as Nocardioforms in
 Bergey's Manual of Systematic Bacteriology (Williams and
 Wilkins, 1986, pp. 1458-1481) include nine genera which
 are close phylogenetically to Corynebacterium,
 Athrobacter and Mycobacterium. Members of the
10 Nocardioforms including the genera Nocardia and
 Rhodococcus exhibit a wide range of useful metabolic
 activities including the assimilation of unusual
 compounds such as alkanes and aromatic hydrocarbons; the
 degradation of lignin, detergents and pesticides; the
15 production of enzymes useful in xenobiotic
 transformations; and the biosynthesis of antibiotics,
 amino acids and biosurfactants. In particular, this
 group of bacteria have been exploited for their
 production of important steroid modifying enzymes,
20 including cholesterol esterase and cholesterol oxidase,
 which are used in diagnostic assays to determine
 cholesterol levels in blood and serum.

 The capacity to degrade cholesterol is
 widespread among microorganisms other than the
25 Nocardioforms. For example, cholesterol oxidases have
 also been isolated from species of Mycobacterium,
 Pseudomonas, and Streptomyces. It is well known from
 scientific and patent literature and from commercial
 practice that the Nocardioform-type cholesterol oxidase
30 is distinct from the other microbial cholesterol
 oxidases.

 The Nocardioform enzyme is very stable and
 active over a wide pH range (pH 6.0 - 8.0), the Km for
 cholesterol is 1.4×10^{-5} mol/liter at 25°, and the

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enzyme is highly specific for Δ^4 - or Δ^5 -3 β -sterols. As produced in the Nocardioforms, cholesterol oxidase is membrane associated and requires detergent extraction and lipid removal for purification.

5 Singer, et al., J. Bacteriol., 1988, Vol. 170, pp. 638-645, describes expression of genes in Rhodococcus sp. from both E. coli and Streptomyces sp. and the development of a shuttle plasmid based on an E. coli plasmid and containing a Rhodococcus 10 plasmid-derived origin of replication. The plasmid is capable of replicating in E. coli and in several but not all of the Rhodococcus species tested.

Summary of the Invention

15 We have discovered that recombinant DNA sequences derived from Nocardioform microorganisms can be expressed efficiently in a host microorganism.

The invention features, in one aspect, a cloning vector which expresses DNA sequences, derived from a Nocardioform organism, in a host microorganism. 20 In preferred embodiments, the DNA sequence is derived from Rhodococcus sp. NCIB 10554 (National Collection of Industrial Bacteria, Aberdeen, Scotland); the DNA sequence encodes cholesterol oxidase; the organism in which the cloning vector can express the Nocardioform 25 DNA is a gram-positive microorganism, more preferably a species of Streptomyces, and most preferably S. lividans; and the cloning vector is the plasmid pSL81.

30 Cholesterol oxidase is produced according to the invention by providing a cloning vector containing a DNA sequence encoding cholesterol oxidase, which is derived from a Nocardioform microorganism, transforming a host cell with the cloning vector to obtain a recombinant host cell, culturing the recombinant host cell under conditions permitting expression of the DNA

sequence, and recovering the cholesterol oxidase. In preferred embodiments, the Nocardioform organism is Rhodococcus sp. NCIB 10554; the host cell is a gram-positive microorganism, preferably a species of Streptomyces, and more preferably S. lividans; and the cloning vector is the plasmid pSL81.

Cholesterol oxidase produced according to the invention can be used for determining cholesterol in a sample, by contacting the sample with the recombinant cholesterol oxidase and determining the extent of oxidation of cholesterol; specifically, by measuring oxygen consumption with an oxygen electrode; or by measuring the production of hydrogen peroxide; or by spectrophotometrically determining cholesterol conversion to Δ^4 -cholestenone.

The invention provides for the expression of DNA sequences derived from a Nocardioform microorganism in a host microorganism that is easier to manipulate under conditions of commercial production than is the parent organism itself, and for which cloning techniques are known. Recombinant cholesterol oxidase derived from Nocardioform microorganisms is expressed as an extracellular protein, an expression condition which can lead to substantially higher production of enzyme. Moreover, the expression does not require addition of an inducer, and the expressed enzyme is free of the lipids of the Nocardioform membrane.

Other features and advantages of the invention will be apparent from the following description of the preferred embodiment thereof, and from the claims.

Description of the Preferred Embodiment

The drawing will first be described.

Drawing

Fig. 1 is a restriction endonuclease map of plasmid pSL81.

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Fig. 2 (2.1-2.6) is a sequence description of the Rhodococcus 10554 cholesterol oxidase gene.

Fig. 3 is a restriction endonuclease map of plasmid pSL81, showing the position of the pSL81Δ15 fragment.

Gene Isolation and Expression

The expression of DNA sequences derived from a Nocardioform microorganism can be accomplished, in general, by first constructing a genomic bank or library by incorporating the DNA sequences into a suitable cloning vector containing a suitable origin of replication compatible with the desired host organism. Next, a host cell from any microorganism, advantageously any gram-positive microorganism, such as, for example, species of Streptomyces or Bacillus, is transformed with the vector containing the DNA sequences. Then, transformants are screened for the activity of the desired gene product, and active clones are isolated and characterized.

Construction of Library

The following protocol, presented for illustrative purposes, describes construction of a genomic library of Rhodococcus sp. NCIB 10554 (Rhodococcus 10554) DNA in a host such as S. lividans which is capable of expressing the DNA from the parent microorganism. In the example described below, a population of transformed cells prepared using this library is screened for the expression of the cholesterol oxidase gene of Rhodococcus 10554.

Generally, a genomic library of Rhodococcus 10554 DNA was constructed from high molecular weight DNA which had been isolated and fragmented with the restriction enzyme Sau3A to yield fragments in the size range 4-8 kilobase pairs. Size fractionated DNA from Rhodococcus 10554 was then ligated to the cloning

plasmid pIJ702 which had been digested with BglII. The pIJ702 plasmid is commercially available through the American Type Culture Collection (Rockville, MD, USA). Hybrid plasmids of the library were transformed into S. lividans cells to generate the genomic library of Rhodococcus 10554 DNA in the host microorganism.

Details of the procedure were as follows: A single colony of Rhodococcus 10554 was used to inoculate 50 ml of NBYE medium which contained per liter: Difco nutrient broth, 8g, and Difco yeast extract, 5g. Other appropriate media described for growing Rhodococcus sp. could also be used. The culture was grown for 48 hours at 30°C and the cells collected by centrifugation at 10,000 rpm for 15 minutes in a Sorvall RC-5B centrifuge using an SS-34 rotor. The cells were resuspended in 18 ml of Tris-glucose (10mM Tris-HCl, pH 8.0, 10mM EDTA, 25% w/v glucose), and 2 ml of lysozyme solution (10 mg/ml lysozyme (Sigma) in Tris-glucose solution) was added. This mixture was incubated at 37°C for 60 minutes. Next, 2.4 ml of 10% w/v sodium dodecyl sulfate (Sigma) was added and the mixture stirred vigorously to form a homogenous solution of lysed cells. The lysed cells were incubated at 55°C for 2 hours, and then 2.7 ml of 5M NaClO₄ (Sigma) were added. Denatured protein and cell debris were removed by extracting the lysed cell solution twice with 20 ml chloroform:isoamyl alcohol (24:1) and resolving the phases by centrifugation at 12,000 rpm for 10 minutes in a Sorvall SS-34 rotor. The aqueous phase was removed and two volumes of cold ethanol added. The solution was mixed gently, and the high molecular weight DNA was collected using a glass rod as described by Marmur et al., 1961, J. Mol. Biol., Vol. 3, pp. 203-218. The collected DNA was washed twice in 70% ethanol and dissolved in 5 ml TE

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(10mM Tris, 1mM EDTA, pH 8.0). DNase free RNase (Sigma) was added at 100 mg/ml to the DNA solution and incubated at 42°C for 30 minutes. Next, 0.6 ml of 10% w/v of sodium dodecyl sulfate and 0.6 ml of 5M NaCl were added, and the mixture was extracted once with phenol:chloroform (1:1) and once with chloroform:isoamyl alcohol (24:1). DNA was precipitated with 2 volumes of ethanol and collected as before using a glass rod. The DNA was washed once with 70% ethanol and air dried prior to resuspension in TE to a final concentration of approximately 1 mg/ml.

In order to establish the condition for isolating partially digested high molecular weight Rhodococcus 10554 DNA, test reactions were set up to digest DNA with different concentrations of Sau3A restriction enzyme. A reaction mixture was prepared with 10 µl DNA, 15 µl 10x Sau3A buffer (200mM Tris HCl, pH 7.4, 50mM MgCl₂, 500mM KCl) and 125 µl water. Aliquots of 15 µl were dispensed into tubes labeled 1-9 and chilled on ice. Exactly 4 units of Sau3A enzyme (10 units/µl BRL) were added to tube 1 and mixed well. Two-fold serial dilutions of the reaction mixtures from tube 1 sequentially through to tube 8 were performed to yield reaction mixtures containing two-fold decreasing concentrations of Sau3A enzyme. Tube 9 which contained no enzyme represented the undigested control reaction. The tubes were incubated at 37°C for 1 hour and stopped by returning the tubes to ice and adding EDTA (20mM). The extent of digestion in each tube was monitored by agarose gel electrophoresis, and the sample which yielded DNA fragments in the approximate range of 2-20 kb was scaled up 200 fold and the reaction repeated. The digested Rhodococcus 10554 DNA was separated by agarose gel

electrophoresis using low gelling temperature agarose (SeaPlaque, FMC). The region of the gel containing DNA fragments in the size range 4-8 kb was excised with a sterile scalpel and the DNA recovered by electro-
5 elution. The DNA was precipitated by conventional methods, and the precipitate was resuspended in TE to a concentration of 0.025 mg/ml.

A single colony of S. lividans/pIJ702 was used to inoculate 50 ml of YEME which contained per liter:
10 Difco yeast extract, 3g; Difco peptone, 5g; Oxoid malt extract, 3g; glucose, 10g; sucrose, 340g; $MgCl_2$ at 5mM; and glycine at 0.4% w/v; and was supplemented with the plasmid selective agent thiostrepton (CalBiochem), at 50 μ g/ml. Other media described for Streptomyces
15 could also be used. The culture was incubated at 30°C for 3 days. The cells were harvested by centrifugation at 10,000 rpm for 30 minutes using a Sorvall centrifuge and SS-34 rotor. The pellet was resuspended in 5ml TSE Buffer (25mM Tris, pH 8.0; 0.3M sucrose; 25mM EDTA)
20 containing 10 mg lysozyme. The cells were incubated at 37°C for 30 minutes. A 3 ml volume of alkaline SDS solution (0.3M NaOH, 2% w/v sodium dodecyl sulfate) was added, and the mixture was incubated at room temperature for 10 minutes and at 70°C for 10 minutes. The lysed
25 cell solution was cooled to room temperature and extracted with 1 volume of phenol: chloroform (1:1). The aqueous phase was removed to a clean tube and 0.3M sodium acetate, pH 4.8, and 1 volume of isopropanol added. The DNA was precipitated for 30 minutes at -20°C
30 and recovered by centrifugation, using a Sorvall SS-34 rotor at 10,000 rpm for 10 minutes. The pellet was resuspended in 2 ml TE and the plasmid DNA purified by ultracentrifugation to equilibrium in a cesium chloride density gradient according to known techniques.

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Plasmid pIJ702 prepared as above was resuspended in TE to a concentration of 1 mg/ml. About 10 μ l (10 μ g) of DNA was added to 5 μ l 10x BglIII buffer (500mM Tris HCl, pH 7.4; 50mM MgCl₂; 500mM KCl), 32 μ l distilled water and 3 μ l of BglIII restriction enzyme (10 units/ μ l, BRL) and incubated for 2 hours at 37°C. The reaction was terminated by one extraction with phenol:chloroform (1:1) and one extraction with chloroform:isoamyl alcohol (24:1). The DNA was precipitated by the addition of one-half volume of 7.5M ammonium acetate and 2 volumes of cold ethanol. After incubation at -20°C for at least 2 hours, the DNA was collected in an Eppendorf microfuge by centrifugation for 10 minutes. The DNA pellet was washed once with 70% ethanol, dried and resuspended in 50 μ l 10mM Tris HCl, pH 8.0. To dephosphorylate the DNA, 1 μ l of calf intestine alkaline phosphatase (2 U/ μ l, IBI) was added and the reaction incubated at 37°C for 30 minutes. The reaction was stopped by adding 150 μ l stop buffer (10mM Tris HCl, pH 7.5; 1mM EDTA, pH 7.5; 200mM NaCl; 0.5% w/v sodium dodecyl sulfate) and then extracted once with phenol:chloroform (1:1) and once with chloroform:isoamyl alcohol (24:1). The DNA was precipitated with ethanol, dried and resuspended in TE to a final concentration of 0.05 mg/ml and stored at -20°C.

About 10 μ l (0.5 μ g) of the dephosphorylated BglIII digested pIJ702 DNA was added to about 20 μ l (0.5 μ g) of the Sau3A digested Rhodococcus DNA. A 20 μ l aliquot of 5x ligase buffer (BRL), 0.5 μ l ligase (NEB) and 50 μ l water were added and the ligation reaction incubated at 14°C for 20 hours. The reaction was terminated by heating the mixture to 65°C for 10 minutes, and the sample was stored at -20°C.

A vegetative inoculum was prepared by growing S. lividans in 25 ml culture broth as described for the preparation of S. lividans/pIJ702, except the medium contained no thiostrepton. The cells were harvested in
5 a benchtop centrifuge at 3,000 rpm for 10 minutes and washed twice with 10 ml of 10.3% w/v sucrose. The cell pellet was resuspended in 4ml lysozyme medium (L-medium, Thompson et al., 1982, J. Bacteriol., Vol. 151, pp. 668-677) and incubated at 30°C for 30 minutes. A 5 ml
10 aliquot of protoplast medium (P-medium, Okanishi, et al., 1974, J. Gen. Microbiol., Vol. 80, pp. 389-400) was added and the solution mixed by pipetting up and down. Protoplasts were filtered through glass wool (which traps mycelia but allows protoplasts to pass through)
15 harvested by centrifugation, and resuspended in 2 ml P-medium. Protoplasts were used fresh or stored frozen in P-medium at -70°C.

Up to 3 µl of ligated plasmid DNA in ligation buffer was mixed gently with 50 µl S. lividans
20 protoplasts in a small sterile tube. To this mixture, 200 µl transformation buffer (T-buffer, Thompson, et al., 1982, J. Bacteriol., Vol. 151, pp. 668-667) was added and pipetted to mix. Immediately, the cells were spread gently onto R2YE medium (Thompson, et al., 1980,
25 Nature (London), Vol. 286, pp. 525-527) and incubated overnight at 30°C. The regenerated protoplasts were overlaid with filter paper (Whatman 541, 9.0cm) containing 100 µg/ml thiostrepton and incubated at 30°C for 3 days. About 200-500 transformants per plate
30 were obtained using these transformation conditions. Approximately 12,000 thiostrepton-resistant S. lividans transformants were obtained in this way. Over 70% of these transformants contained recombinant pIJ702 plasmids as estimated by miniprep DNA analysis. These

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recombinant plasmids represented the genomic library of Rhodococcus 10554 DNA.

Screening for Cholesterol Oxidase Activity

As an example, showing the expression of one DNA sequence derived from a Nocardioform microorganism, recombinant S. lividans cells containing the genomic library of Rhodococcus 10554 DNA were screened for the expression of cholesterol oxidase activity. Cholesterol oxidase was determined using a modified method of Allain et al., 1974, Physical Chem., Vol. 20, pp. 470-475.

Filter paper discs were soaked in an assay buffer containing 4-aminoantipyrine, phenol, horse radish peroxidase and triton-X100, and laid down on colonies growing on agar medium containing cholesterol substrate. Alternatively, these colonies could be assayed by halo formation on agar medium containing cholesterol, in which halo formation depended on the conversion of cholesterol to cholestenone by soluble cholesterol oxidase. Recombinant S. lividans colonies which produced cholesterol oxidase were purified, and characterized.

Details of the screening of the genomic library for cholesterol oxidase activity were as follows:

Filter papers used to apply thiostrepton drug to R2YE transformation plates for the selection of S. lividans transformants, were lifted and placed onto screening plates [medium containing per liter: agar, 15g; glycerol, 20g; yeast extract, 1g; MgSO_4 , 0.66g; buffer salts, 66 ml (per liter: Na_2HPO_4 , 28g; NaH_2PO_4 , 30g; K_2HPO_4 , 20g; $(\text{NH}_4)_2\text{SO}_4$, 127.5 g) and trace salts, 2 ml (per liter: concentrated HCl, 250 ml; CaCl_2 , 3.57g; ZnSO_4 , 20g; CuCl_2 , 0.85g; NaMoO_4 , 4.8g; MnCl_2 , 2.0g; FeCl_3 , 5.4g; boric acid, 0.3g; CoCl_2 , 2.4g)] with cholesterol (1.6mM, Sigma) and

thiostrepton (50 µg/ml). These replica plates were incubated at 30°C for 3 days. The replica filters were removed and replaced with sterile filter paper discs soaked in cholesterol oxidase assay reagent (100mM
5 citric acid buffer, pH 6.0; 0.2mM 4-aminoantipyrine (Aldrich); horse radish peroxidase I, 600 units per liter; 6.4mM cholesterol; 10mM phenol and 4% w/v Triton x 100). The plates were incubated at 30°C, and the colonies were screened over a 4 hour period for the
10 development of a red zone due to cholesterol oxidase activity which diffused onto the white filter paper. After incubation at 30°C for 4 hours, the assay reagent filter papers were removed from the screening plates, and the plates were re-incubated at 30°C overnight to
15 allow for the formation of clear halos associated with cholesterol oxidase degradation of cholesterol. From the approximately 8,000 recombinant S. lividans colonies screened, two showed cholesterol oxidase activity. The plasmid DNA from one of these isolates was called pSL81
20 and was analyzed further.

Plasmid DNA from the S. lividans/pSL81 recombinant was isolated and transformed back into S. lividans using the same procedure described for
isolating and transforming pIJ702. All the
25 thiostrepton-resistant transformants obtained contained the same plasmid pIJ702 with approximately 6 kb insert DNA, and showed the cholesterol oxidase activity diagnostic of the original recombinant. Curing of
plasmid pSL81 from S. lividans cells by growth in the
30 absence of drug selective pressure resulted in the simultaneous loss of thiostrepton resistance and cholesterol oxidase activity. Southern hybridization demonstrated that the insert DNA was derived from the Rhodococcus 10554 genome. Referring to Fig. 1, the

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recombinant plasmid designated pSL81 includes cloning vector pIJ702 12 and insert DNA 14 from Rhodococcus 10554, and has restriction endonuclease sites as indicated.

5 Plasmid pSL81, prepared as above, was used to probe chromosomal digests from the cholesterol oxidase producing Nocardioforms Rhodococcus NCIB 10554, R. erythropolis NCIB 9158, Nocardia erythropolis ATCC 17895 and Nocardia erythropolis ATCC 4277. The strains all
10 showed cross-hybridizing DNA bands suggesting that the cholesterol oxidase coding region in these Nocardioforms is the same. Plasmid pSL81 showed no specific cross hybridization with DNA isolated from a cholesterol oxidase producing Streptomyces, namely Streptomyces
15 violascens NRRL B-2700.

DNA Sequencing

In order to sequence the cholesterol oxidase gene, subclones of pSL81 were constructed and a cholesterol oxidase coding region was localized to a
20 2.8 kb BglII fragment in the subclone pSL81Δ15 (Fig. 3). This fragment was then introduced into E. coli on plasmid pBR322, and a series of deletion derivatives were constructed using available restriction sites. Sequencing was performed on denatured double
25 stranded plasmid DNA using the dideoxy chain termination method of Sanger et al., PNAS USA, Vol. 74, pp. 5463-67. Specifically, a Sequenase Version 2.0 kit (United States Biochemical Corp.) was used according to the manufacturer's specifications. Deoxyguanine
30 triphosphate or Deoxy-7-deazoguanidine triphosphate was used to terminate chain polymerization reactions depending on the degree of G+C content of a particular region of DNA being sequenced. The primer extended oligonucleotides were electrophoresed on denaturing 6%

polyacrylamide and the DNA sequences of adjacent DNA fragments were pieced together to construct a complete DNA sequence of the cholesterol oxidase gene. The sequence is shown in Fig. 2.

5 Subcloning of the Rhodococcus cholesterol oxidase gene in pSL81Δ15 can result in an increase in expression of the cholesterol oxidase protein. Recombinant S. lividans cells were grown on RZYE agar containing 50μg/ml thiostrepton. After 2-3 days
10 incubation at 30°C, the mycelia and spores were scraped from the surface of the agar and used to inoculate 50 ml YEME + 12.5 μg/ml thiostrepton seed cultures. These cultures were grown at 30°C with vigorous shaking and after 48 h, 2 l fermenters containing YEME + 12.5
15 μg/ml thiostrepton were inoculated with the seed. The fermentations were controlled at 28°C and pH 7.0 with aeration at 0.5 l/min and agitation at 1000 rpm. Cholesterol oxidase activity peaked after 48 h and in some such cultures expression was substantially greater
20 in the S. lividans/pSL81Δ15 fermentations than in the S. lividans/pSL81 fermentations.

Protein characterization

Recombinant cholesterol oxidase was isolated from 3 day old cultures of S. lividans/pSL81 cells grown
25 in YEME (25 ml) containing thiostrepton (50 μg/ml). Non-recombinant cholesterol oxidase was isolated from 48 hour Rhodococcus 10554 cultures grown in liquid production medium which was the same medium as that used for the screening plates not solidified with agar.
30 Induction experiments were performed using the same growth conditions in the presence of sterol as an inducer. Intracellular and extracellular fractions were recovered by centrifugation and assayed for cholesterol oxidase activity using a cholesterol oxidase specific diagnostic assay. The specificity of the recombinant

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cholesterol oxidase from S. lividans and the purified cholesterol oxidase from Rhodococcus 10554 were compared using various sterol substrates. Both enzymes showed similar profiles with the order of activity being cholesterol, pregnenolone, dihydroxycholesterol, stigmasterol and ergosterol.

Recombinant cholesterol oxidase from S. lividans/pSL81 was functional in standard diagnostic assays for the determination of cholesterol. An aliquot of cell-free supernatant from a 3 day old culture of YEME grown recombinant cells was mixed with the cholesterol oxidase assay reagent (1.4 ml of 0.33 mg/ml 4-aminophenazone in 0.1M phosphate buffer, pH 7.0, 0.05% Triton X-100 (w/v); 1.4 ml of 1 mg/ml phenol in phosphate-Triton X buffer; 0.1 ml of 4mM cholesterol; and 0.01 ml of 10 mg/ml peroxidase) and incubated at 30°C. Hydrogen peroxide formed during the oxidation of cholesterol and chelated with the aminoantipyrine in the assay mixture was determined by measuring the absorption of the red complex at 505nm versus a reagent blank containing water. The rate of cholesterol degradation by the recombinant enzyme was also measured directly by following the increase in absorbance at 240 nm owing to Δ^4 -cholestenone production. To 2.9 ml of sodium phosphate buffer (0.1M, pH 7.0) in a cuvette, 100 μ l of 3% Triton X-100 (w/v) and 50 μ l of a 6mM cholesterol solution were added. Diluted enzyme at approximately 0.2 U/ml in buffer was added and the absorbance at 240nm monitored using a Beckman spectrophotometer. Cholesterol oxidase activity was calculated as:

$$\text{units/mg} = \frac{\text{OD/min} \times \text{RV}}{12.3 \times \text{DF} \times \text{SV} \times \text{PC (mg/ml)}},$$

where

RV = reaction volume

DF = dilution factor

SV = sample volume

5 PC = protein concentration

Further characterization of the recombinant cholesterol oxidase from S. lividans/pSL81 demonstrated that the enzyme could also be used to determine cholesterol in sera using the peroxidase coupled reaction.

10 Recombinant cholesterol oxidase from S. lividans/pSL81 and purified Rhodococcus 10554 cholesterol oxidase were analyzed by polyacrylamide gel electrophoresis using a 10% polyacrylamide gel and the buffer system of Laemmli, 1970, Nature, Vol. 227, pp. 15 680 et seq. Both enzymes were determined to be approximately 55 kD in size when compared with Biorad molecular weight standards.

Peptide sequencing

Recombinant cholesterol oxidase from
20 S. lividans/pSL81Δ15 and non-recombinant cholesterol oxidase from R. rhodococcus were isolated as single bands from a polyacrylamide gel, and the amino-terminal peptide sequences were determined using a protein sequenator. Two peptide sequences were recovered from
25 the recombinant protein band:
NH₂-Gly-Gly-Pro-Val-Ser-Thr-Leu-Thr-Pro-Pro-Pro-Ala-Phe-,
and

NH₂-Gly-Pro-Val-Ser-Thr-Leu-Thr-Pro-Pro-Pro-Ala-Phe-.
These peptide sequences are identical to those deduced
30 directly from the DNA sequence between positions 280 and 320, and between positions 283 and 320, respectively. The elimination of a glycine residue at the N-terminus of one recombinant sequence is probably owing to a

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difference in post-translational processing by the host cell.

Amino terminal sequencing of cholesterol oxidase from R. rhodococcus identified the sequence
5 NH₂-Thr-Pro-Pro-Pro-Ala-Phe-Pro-Glu-Gly-Ile-Ala-Leu-Tyr-Gln-Gln-,

which corresponds to the peptide sequence deduced from the DNA sequence between positions 300 and 346.

Therefore, the enzyme found in the

10 S. lividans/pSL81Δ15 culture medium is either 6 or 7 amino acids longer than the membrane bound enzyme found in R. rhodococcus.

Processing of gram-positive secreted proteins often involves signal sequence cleavage followed by
15 hydrolysis at a secondary processing site. In the case of native cholesterol oxidase this secondary site is at the threonine. Apparently such a secondary cleavage does not occur when the protein is synthesized and secreted extracellularly by S. lividans.

20 Other Embodiments

Other embodiments are within the following claims. For example, other species of any genus of the Nocardioforms including Rhodococcus NCIB 10554, R. erythropolis NCIB 9158, Nocardia erythropolis ATCC 17895
25 and Nocardia erythropolis ATCC 4277 could be used to prepare the genomic library; or the libraries could be screened for other useful metabolic activities such as the assimilation of alkanes and aromatic hydrocarbons; the degradation of lignin, detergents, and pesticides;
30 the production of enzymes useful in xenobiotic transformation; the biosynthesis of antibiotics, amino acids and biosurfactants; and the production of other steroid modifying enzymes such as cholesterol esterase.

As other Streptomyces and also Bacillus species

share the advantages of S. lividans for the expression of heterologous genes, they could also serve as suitable hosts for the expression of DNA sequences derived from Nocardioform microorganisms. Other bacteria belonging to the high G+C subdivision of the gram-positive bacteria including any of the Nocardioforms, Mycobacterium, Corynebacterium, and Athrobacter would be suitable hosts for cloning DNA sequences derived from Nocardioform microorganisms.

S. lividans/pSL81 can undergo rearrangement in one or more regions outside the cholesterol oxidase coding region and can retain cholesterol oxidase transforming activity. One such S. lividans/pSL81 rearranged plasmid, has at least 3.6 kb of the 6 kb Rhodococcus DNA unchanged as determined by restriction mapping. In this rearranged S. lividans/pSL81 plasmid a DNA insertion of approximately 2.5 kb has occurred in the region to the right of the PvuII site. Cholesterol oxidase was recoverable from cultures of S. lividans transformed with this rearranged plasmid, in lower quantities than from S. lividans/pSL81 cultures.

In still other embodiments expression of cholesterol oxidase may be increased by further manipulating the pSL81Δ15 clone, as will be apparent to one skilled in the art. For example, a higher copy number vector could be used, such as, for example, pIJ303, described in Hopwood et al., 1985, Genetic Manipulation of Streptomyces: A Laboratory Manual. Gene expression could also be enhanced by replacing the cholesterol oxidase promoter with a stronger exogenous promoters, such as ErmE promoter, described in Bibb et al., 1985, Gene, Vol. 38, pp. 215-226; aph promoter, described in Hopwood et al., 1985; or a tac promoter,

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described in Amman et al., 1984, Gene, Vol. 25, pp. 167
et seq.

Deposit

Under the terms of the Budapest Treaty on the
5 International Recognition of the Deposit of
Microorganisms for the Purpose of Patent Procedure,
deposit of plasmid pSL81 has been made with the American
Type Culture Collection (ATCC) of Rockville, MD, USA,
where the deposit was given Accession Number ____.

10 Applicants' assignee, Genzyme Corporation,
represents that the ATCC is a depository affording
permanence of the deposit and ready accessibility
thereto by the public if a patent is granted. All
restrictions on the availability to the public of the
15 material so deposited will be irrevocably removed upon
the granting of a patent. The material will be
available during the pendency of the patent application
to one determined by the Commissioner to be entitled
thereto under 37 CFR 1.14 and 35 U.S.C. § 122. The
20 deposited material will be maintained with all the care
necessary to keep it viable and uncontaminated for a
period of at least five years after the most recent
request for the furnishing of a sample of the deposited
plasmid, and in any case, for a period of at least
25 thirty (30) years after the date of deposit or for the
enforceable life of the patent, whichever period is
longer. Applicants' assignee acknowledges its duty to
replace the deposit should the depository be unable to
furnish a sample when requested due to the condition of
30 the deposit.

Claims

- 1 1. A cloning vector comprising a DNA sequence
2 derived from a Nocardioform microorganism, said DNA
3 sequence encoding a protein, and said cloning vector
4 being capable of expressing said DNA sequence in a host
5 microorganism.
- 1 2. The cloning vector of claim 1 wherein said
2 Nocardioform microorganism is Rhodococcus sp. NCIB 10554.
- 1 3. The cloning vector of claim 1 wherein said
2 host microorganism is a gram-positive microorganism.
- 1 4. The cloning vector of claim 1 wherein said
2 host microorganism is a species of Streptomyces.
- 1 5. The cloning vector of claim 1 wherein said
2 host microorganism is S. lividans.
- 1 6. The cloning vector of claim 1 wherein said
2 DNA sequence encodes cholesterol oxidase.
- 1 7. The plasmid pSL81.
- 1 8. A microorganism transformed with the
2 cloning vector of claim 1 or 2.
- 1 9. A gram-positive microorganism transformed
2 with the cloning vector of claim 3.
- 1 10. A cell of a species of Streptomyces
2 transformed with the cloning vector of claim 4.
- 1 11. A cell of the species S. lividans
2 transformed with the cloning vector of claim 5.
- 1 12. A method for expressing a DNA sequence
2 derived from a Nocardioform microorganism comprising
3 providing a cloning vector containing said DNA
4 sequence,
5 transforming a host microbial cell with said
6 cloning vector to obtain a recombinant host cell, and
7 culturing said recombinant host cell under
8 conditions permitting expression of said DNA sequence.

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1 13. A method for producing cholesterol oxidase
2 comprising

3 providing a cloning vector containing a DNA
4 sequence derived from a Nocardioform microorganism, said
5 DNA sequence encoding cholesterol oxidase,

6 transforming a host cell with said cloning
7 vector to obtain a recombinant host cell,

8 culturing said recombinant host cell under
9 conditions permitting expression of said DNA sequence,
10 and

11 recovering the cholesterol oxidase.

1 14. The method of claim 13 wherein said
2 Nocardioform organism is Rhodococcus sp. NCIB 10554.

1 15. The method of claim 13 wherein said host
2 cell is a gram-positive microorganism.

1 16. The method of claim 13 wherein said host
2 cell is a Streptomyces sp.

1 17. The method of claim 13 wherein said host
2 cell is S. lividans.

1 18. The method of claim 13 wherein said
2 cloning vector is plasmid pSL81.

1 19. Recombinant cholesterol oxidase encoded by
2 DNA derived from a Nocardioform microorganism.

1 20. Recombinant cholesterol oxidase encoded by
2 DNA derived from Rhodococcus sp. NCIB 10554.

1 21. Cholesterol oxidase of claim 19 or 20,
2 essentially free of lipids found in said Nocardioform
3 microorganism.

1 22. Cholesterol oxidase of claim 19 or 20
2 produced in a transformed heterologous host
3 microorganism.

1 23. Cholesterol oxidase of claim 19 or 20
2 produced in a transformed host gram-positive
3 microorganism.

1 24. Cholesterol oxidase of claim 19 or 20
2 produced in a transformed species of Streptomyces.

1 25. Cholesterol oxidase of claim 19 or 20
2 produced in transformed S. lividans.

1 26. Cholesterol oxidase of claim 19 or 20
2 produced substantially in extracellular form.

1 27. Cholesterol oxidase of claim 19 or 20
2 expressed without the addition of inducer.

1 28. A cell transformed with a DNA sequence
2 derived from a Nocardioform microorganism, said DNA
3 sequence encoding cholesterol oxidase.

1 29. A method for the determination of
2 cholesterol in a sample of fluid from a human comprising
3 contacting said sample with recombinant
4 cholesterol oxidase encoded by DNA derived from a
5 Nocardioform microorganism and
6 determining the extent of oxidation of
7 cholesterol.

1 30. The method of claim 30 wherein determining
2 the extent of oxidation of cholesterol comprises
3 measuring the consumption of oxygen with an
4 oxygen electrode.

1 31. The method of claim 30 wherein determining
2 the extent of oxidation of cholesterol comprises
3 measuring the production of hydrogen peroxide.

1 32. The method of claim 30 wherein determining
2 the extent of oxidation of cholesterol comprises
3 spectrophotometrically determining the
4 conversion of cholesterol to Δ^4 -cholestenone.

1 33. The cloning vector of claim 1, wherein
2 said DNA sequence encodes an amino acid sequence
3 comprising the sequence:

4 Thr Pro Pro Pro Ala Phe Pro Glu Gly Ile Ala Leu
5 Tyr Gln Gln.

1 34. The cloning vector of claim 33, wherein
2 said DNA sequence encodes an amino acid sequence
3 comprising the sequence:

4 Gly Pro Val Ser Thr Leu Thr Pro Pro Pro Ala Phe
5 Pro Glu Gly Ile Ala Leu Tyr Gln Gln.

1 35. The cloning vector of claim 34, wherein
2 said DNA sequence encodes an amino acid sequence
3 comprising the sequence:

4 Gly Gly Pro Val Ser Thr Leu Thr Pro Pro Pro Ala
5 Phe Pro Glu Gly Ile Ala Leu Tyr Gln Gln.

1 36. The cloning vector of claim 35, wherein
2 said DNA sequence encodes an amino acid sequence
3 comprising the sequence:

4 Met Thr Ala Gln Asp Glu Lys Phe Arg Leu Ser Arg
5 Arg Gly Phe Met Ala Ala Gly Ala Gly Ala Val Ala Ala Thr
6 Ala Phe Ala Gly Trp Thr Pro Ala Tyr Ala Val Pro Ala Gly
7 Ser Ser Gly Ser Ala Gly Gly Pro Val Ser Thr Leu Thr Pro
8 Pro Pro Ala Phe Pro Glu Gly Ile Ala Leu Tyr Gln Gln Ala
9 Tyr Gln Asn Trp Ser Lys Glu Ile Met Leu Asp.

1 37. The cloning vector of claim 1, wherein
2 said DNA sequence comprises the sequence:

3 ACA CCG CCG CCC GCC TTC CCC GAA GGC ATC GCG CTG TAC CAG
4 CAG

1 38. The cloning vector of claim 37, wherein
2 said DNA sequence comprises the sequence:

3 GGT CCT GTC TCC ACC CTC ACA CCG CCG CCC GCC TTC CCC GAA
4 GGC ATC GCG CTG TAC CAG CAG

1 39. The cloning vector of claim 38, wherein
2 said DNA sequence comprises the sequence:

3 GGT GGT CCT GTC TCC ACC CTC ACA CCG CCG CCC GCC TTC CCC
4 GAA GGC ATC GCG CTG TAC CAG CAG

1 40. The cloning vector of claim 39, wherein
2 said DNA sequence comprises the sequence:
3 CGAAG ATG ACG GCA CAA GAC GAA AAG TTC CGA CTG TCC CGA
4 CGA GGT TTC ATG GCC GCT GGA GCC GGC GCC GTG GCA GCG ACC
5 GCA TTC GCC GGC TGG ACG CCG GCC TAC GCC GTC CCC GCC GGC
6 TCC TCC GGC TCC GCG GGT GGT CCT GTC TCC ACC CTC ACA CCG
7 CCG CCC GCC TTC CCC GAA GGC ATC GCG CTG TAC CAG CAG GCA
8 TAT CAG AAC TGG TCC AAA GAG ATC ATG CTC GAC

1 41. The cloning vector of claim 40, wherein
2 said DNA sequence comprises the sequence:
3 GGGACTCCTG ATCTCAGCTT CCGTACTGGA GCGCGAAGCT CCTGCCCTGG
4 CTGACGTAGT TCTCACTCTT GTCTGATACC AACCTGTCTG ATACCCACCT
5 GTTAGAACTC ACCGTAGTTC TCGAACCCGA TGGAGTAGCC CGAAG ATG
6 ACG GCA CAA GAC GAA AAG TTC CGA CTG TCC CGA CGA GGT TTC
7 ATG GCC GCT GGA GCC GGC GCC GTG GCA GCG ACC GCA TTC GCC
8 GGC TGG ACG CCG GCC TAC GCC GTC CCC GCC GGC TCC TCC GGC
9 TCC GCG GGT GGT CCT GTC TCC ACC CTC ACA CCG CCG CCC GCC
10 TTC CCC GAA GGC ATC GCG CTG TAC CAG CAG GCA TAT CAG AAC
11 TGG TCC AAA GAG ATC ATG CTC GAC

1 42. The cloning vector of claim 1 wherein said
2 Nocardioform microorganism is R. erythropolis NCIB 9158.

1 43. The cloning vector of claim 1 wherein said
2 Nocardioform microorganism is Nocardia erythropolis ATCC
3 17895.

1 44. The cloning vector of claim 1 wherein said
2 Nocardioform microorganism is Nocardia erythropolis ATCC
3 4277.

1 45. The method of claim 13 wherein said
2 cloning vector is plasmid pIJ303.

1 46. The vector of claim 1, further comprising
2 an ErmE promoter.

1 47. The vector of claim 1, further comprising
2 an aph promoter.

1 48. The vector of claim 1, further comprising
2 a tac promoter.

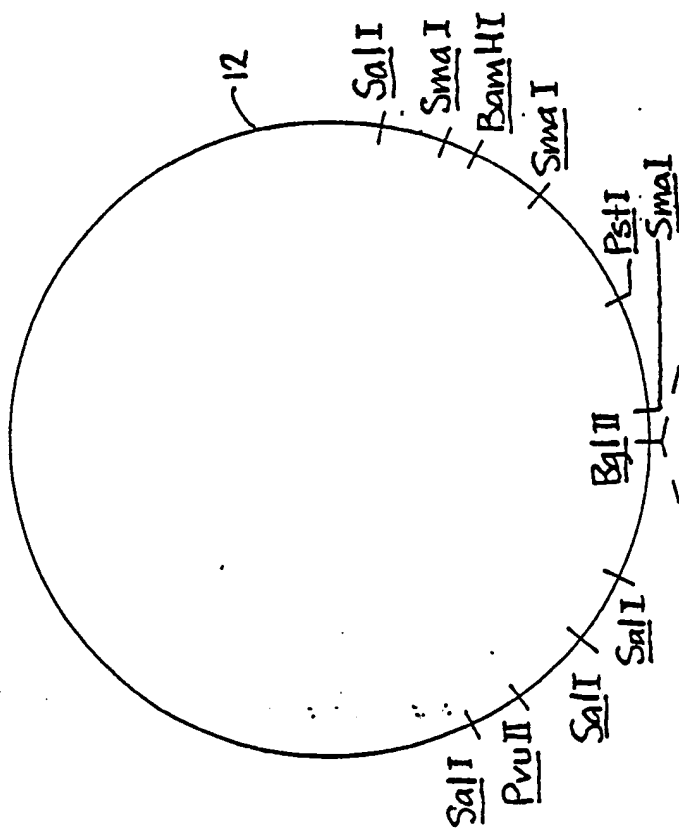


FIG. 1

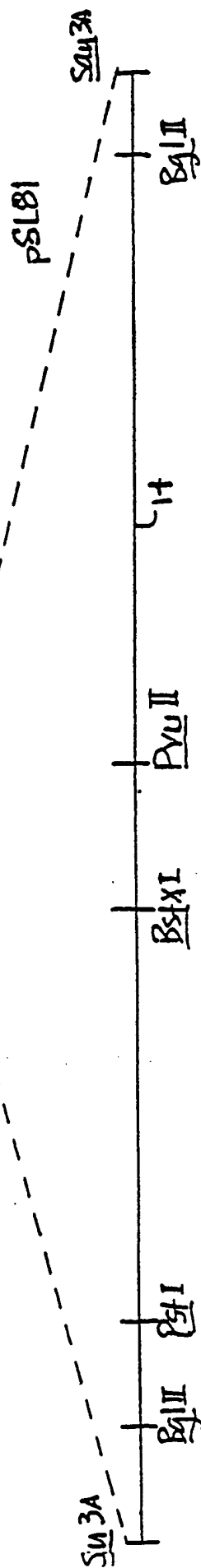


FIG. 3



Translation of CO2 over region 146-2029;.

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      10      20      30      40      50      60      70
      *      *      *      *      *      *      *
GGGACTCCTG ATCTCAGCTT CCGTACTGGA GCGCGAGCT CCGCCCTGG CTGACGTAGT TCTCACTCTT
CCCTGAGGAC TAGAGTCGAA GGCATGACCT CCGCCTTCGA GGACGGGACC GACTGCATCA AGAGTGAGAA

      80      90     100     110     120     130     140
      *      *      *      *      *      *      *
GTCTGATACC AACCTGTCTG ATACCCACCT GTTAGAGCTC ACCGTAGTTC TCGAACCCGA TGGAGTAGCC
CAGACTATGG TTGGACAGAC TATGGGTGGA CAACTCTGAG TGGCATCAG AGCTTGGGCT ACCTCATCGG

      150     160     170     180     190     200
      *      *      *      *      *      *
CGAAG ATG ACG GCA CAA GAC GAA AAG TTC CGA CTG TCC CGA CGA GGT TTC ATG GCC GCT GGA
GCTTC TAC TGC CGT GTT CTG CTT TTC AAG GCT GAC AGG GCT GCT CCA AAG TAC CGG CGA CCT
Met Thr Ala Gln Asp Glu Lys Phe Arg Leu Ser Arg Arg Gly Phe Met Ala Ala Gly
AUTOTRANSLATION OF CO2

      210     220     230     240     250     260
      *      *      *      *      *      *
GCC GGC GCC GTG GCA GCG ACC GCA TTC GCC GGC TGG ACG CCG GCC TAC GCC GTC CCC GCC
CGG CCG CCG CAC CGT CGC TGG CGT AAG CCG CCG ACC TGC GGC CCG ATG CCG CAG GGG CCG
Ala Gly Ala Val Ala Ala Thr Ala Phe Ala Gly Trp Thr Pro Ala Tyr Ala Val Pro Ala
AUTOTRANSLATION OF CO2

      270     280     290     300     310     320
      *      *      *      *      *      *
GGC TCC TCC GGC TCC GCG GGT GGT CCT GTC TCC ACC CTC ACA CCG CCG CCC GCC TTC CCC
CCG AGG AGG CCG AGG CCG CCA CCA GGA CAG AGG TGG GAG TGT GGC GGC GGG CCG AAG GGG
Gly Ser Ser Gly Ser Ala Gly Gly Pro Val Ser Thr Leu Thr Pro Pro Pro Ala Phe Pro
AUTOTRANSLATION OF CO2

      330     340     350     360     370     380
      *      *      *      *      *      *
GAA GGC ATC GCG CTG TAC CAG CAG GCA TAT CAG AAC TGG TCC AAA GAG ATC ATG CTC GAC
CTT CCG TAG CCG GAC ATG GTC GTC CGT ATA GTC TTG ACC AGG TTT CTC TAG TAC GAG CTG
Glu Gly Ile Ala Leu Tyr Gln Gln Ala Tyr Gln Asn Trp Ser Lys Glu Ile Met Leu Asp
AUTOTRANSLATION OF CO2

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FIG. 2.1

390 400 410 420 430 440
 * * * * *
 GCG ATC TGG ACC TGT TCA CCC AAG ACG CCC GAA GAC GTA GTC GCC TCG CGA ACT GGG CCA
 CGC TAG ACC TGG ACA AGT GGG TTC TGC GGG CTT CTG CAT CAG CGG AGC GCT TGA CCC GGT
 Ala Ile Trp Thr Cys Ser Pro Lys Thr Pro Glu Asp Val Val Ala Ser Arg Thr Gly Pro→
 AUTOTRANSLATION OF CO2

450 460 470 480 490 500
 * * * * *
 TCC AAC GGC TAC ACC ATT CGT CCC CGC GGG CCA TGC GTG GAC GCC GCT GAC CAT CGT CAA
 AAG TTG CCG ATG TGG TAA GCA GGG GCG CCC GGT ACG CAC CTG CGG CGA CTG GTA GCA GTT
 Ser Asn Gly Tyr Thr Ile Arg Pro Arg Gly Pro Cys Val Asp Ala Ala Asp His Arg Gln→
 AUTOTRANSLATION OF CO2

510 520 530 540 550 560
 * * * * *
 CCG TGC GCC GGT CGA CAA GGT CAT CCT CGC CGA CAC CAC GGT CCA CCT CAC CGG CGT CTC
 GCC ACG CGG CCA GCT GTT CCA GTA GGA GCG GCT GTG GTG CCA GGT GGA GTG GCC GCA GAG
 Arg Cys Ala Gly Arg Gln Gly His Pro Arg Arg His His Gly Pro Pro His Arg Arg Leu→
 AUTOTRANSLATION OF CO2

570 580 590 600 610 620
 * * * * *
 CGT CAA CGC CGG TGG CAG CCC GGC CAC CGT CAC CGC AGG ACC CGG CGC GAC CCT CGA CGC
 GCA GTT GCG GCC ACC GTC GGG CCG GTG GCA GTG GCG TCC TGG GCC GCG CTG GGA GCT GCG
 Arg Gln Arg Arg Trp Gln Pro Gly His Arg His Arg Arg Thr Arg Arg Asp Pro Arg Arg→
 AUTOTRANSLATION OF CO2

630 640 650 660 670 680
 * * * * *
 CAT CAC CAC CGC ACT GCA GGC ACA GGG CCT CGG GTT CGC GAA CTG CCG GCG CCC GGT GTG
 GTA GTG GTG GCG TGA CGT CCG TGT CCC GGA GCC CAA GCG CTT GAC GGC CGC GGG CCA CAC
 His His His Arg Thr Ala Gly Thr Gly Pro Arg Val Arg Glu Leu Pro Ala Pro Gly Val→
 AUTOTRANSLATION OF CO2

690 700 710 720 730 740
 * * * * *
 TTG ACC ATC GCC GGC TGC CTC GCC GTC GAC GCT CAC GGT GCA GCG CTC CCC GCC GAA GGC
 AAC TGG TAG CCG CCG ACG GAG CCG CAG CTG CCA GTG CCA CGT CGC GAG GGG CGG CTT CCG
 Leu Thr Ile Ala Gly Cys Leu Ala Val Asp Ala His Gly Ala Ala Leu Pro Ala Glu Gly→
 AUTOTRANSLATION OF CO2

750 760 770 780 790 800
 * * * * *
 GAA GCA CAC GTT CCC GGA CAG ACT TTC GGC TCA CTC TCC AAC CTC GTC ACC TCC CTG ACC
 CTT CGT GTG CAA GGG CCT GTC TGA AAG CCG AGT GAG AGG TTG GAG CAG TGG AGG GAC TGG
 Glu Ala His Val Pro Gly Gln Thr Phe Gly Ser Leu Ser Asn Leu Val Thr Ser Leu Thr→
 AUTOTRANSLATION OF CO2

FIG. 2.2

810 820 830 840 850 860
 * * * * *
 GCA GTG GTC TGG AAC GGC AGT GAG TAC GCG CTC GAG ACG TAC GCG CGT AGC GAT GCA GCG
 CGT CAC CAG ACC TTG CCG TCA CTC ATG CCG GAG CTC TGC ATG CCG GCA TCG CTA CGT CCG
 Ala Val Val Trp Asn Gly Ser Glu Tyr Ala Leu Glu Thr Tyr Ala Arg Ser Asp Ala Ala→
 AUTOTRANSLATION OF C02

870 880 890 900 910 920
 * * * * *
 ATC AAG CCG CTG CTG ACT CAC CTC GGA CCG ACC TTC CTC ACC TCC GTG ACC TTG CAG GCC
 TAG TTC GGC GAC GAC TGA GTG GAG CCT GCG TGG AAG GAG TGG AAG CAC TGG AAC GTC CCG
 Ile Lys Pro Leu Leu Thr His Leu Gly Arg Thr Phe Leu Thr Ser Val Thr Leu Gln Ala→
 AUTOTRANSLATION OF C02

930 940 950 960 970 980
 * * * * *
 GCT CCC AAC TAC CCG ATG CCG TGC GTC AGC CAC ACC GAC ATC GGT TGG CAG GAA CTC TTC
 CGA GGG TTG ATG GCG TAC GCG ACG CAG TCG GTG TGG CTG TAG CCA ACC GTC CTT GAG AAG
 Ala Pro Asn Tyr Arg Met Arg Cys Val Ser His Thr Asp Ile Gly Trp Gln Glu Leu Phe→
 AUTOTRANSLATION OF C02

990 1000 1010 1020 1030 1040
 * * * * *
 GGC GCC CCG GGA GCG TCC GGA CCG ACC TTC GAG AAG TTC GTC CCG GAA AAC GGT CCG GCA
 CCG CCG GCG CCT CCG AGG CCT GCG TGG AAG CTC TTC AAG CAG GCG CTT TTG CCA GCG CGT
 Gly Ala Arg Gly Ala Ser Gly Arg Thr Phe Glu Lys Phe Val Arg Glu Asn Gly Arg Ala→
 AUTOTRANSLATION OF C02

1050 1060 1070 1080 1090 1100
 * * * * *
 GAA GCA ATC TGG TAC CCC TTC ACC GAA CCG CCG TGG ATG AAG GTG TGG TCA CTT GCC CCC
 CTT CGT TAG ACC ATG GGG AAG TGG CTT GCG GGC ACC TAC TTC CAC ACC AGT GAA CCG GGG
 Glu Ala Ile Trp Tyr Pro Phe Thr Glu Arg Pro Trp Met Lys Val Trp Ser Leu Ala Pro→
 AUTOTRANSLATION OF C02

1110 1120 1130 1140 1150 1160
 * * * * *
 ACC AAG CCG CCG TTC TCG CGT GAG GTG ACC GGG CCC TAC AAC TAC ATC TTC TCC GAC AAC
 TGG TTC GCC GGC AAG AGC GCA CTC CAC TGG CCC GGG ATG TTG ATG TAG AAG AGG CTG TTG
 Thr Lys Arg Pro Phe Ser Arg Glu Val Thr Gly Pro Tyr Asn Tyr Ile Phe Ser Asp Asn→
 AUTOTRANSLATION OF C02

1170 1180 1190 1200 1210 1220
 * * * * *
 CTC CCG GAG CCG GTC ACC GAC ATG ATC GGG CAG ATC AAC GCC GGA AAC CCG GGC ATC GCA
 GAG GGC CTC GGC CAG TGG CTG TAC TAG CCC GTC TAG TTG CCG CCT TTG GGC CCG TAG CGT
 Leu Pro Glu Pro Val Thr Asp Met Ile Gly Gln Ile Asn Ala Gly Asn Pro Gly Ile Ala→
 AUTOTRANSLATION OF C02

1230 1240 1250 1260 1270 1280
 * * * * * *
 CCG GCA TTC AGG CAG ATC ATG TAC GCC ACC ACC GTT GCC GGA CTC GCC GCG ACC TTC TCC
 GGC CGT AAG TCC GTC TAG TAC ATG CCG TGG TGG CAA CCG CCT GAG CCG CCG TGG AAG AGG
 Pro Ala Phe Arg Gln Ile Met Tyr Ala Thr Thr Val Ala Gly Leu Ala Ala Thr Phe Ser→
 _____ AUTOTRANSLATION OF CO2 _____

1290 1300 1310 1320 1330 1340
 * * * * * *
 AAC GAC CTG TGG GGA TGG TCC AAG GAC GTC CAG TTC TAC ATC CCG GCC ACC ACC CTT CGT
 TTG CTG GAC ACC CCT ACC AAG TTC CTG CAG GTC AAG ATG TAG GCC CCG TGG TGG GAA GCA
 Asn Asp Leu Trp Gly Trp Ser Lys Asp Val Gln Phe Tyr Ile Arg Ala Thr Thr Leu Arg→
 _____ AUTOTRANSLATION OF CO2 _____

1350 1360 1370 1380 1390 1400
 * * * * * *
 CTG ACC GAG GGC GGC GGA GCC GTC ATC ACC TCC CCG GCC AAC ATC GGC CAG GTC ATC CAC
 GAC TGG CTC CCG CCG CCT CCG CAG TAG TGG AAG GCG CCG TTG TAG CCG GTC CAG TAG GTG
 Leu Thr Glu Gly Gly Gly Ala Val Ile Thr Ser Arg Ala Asn Ile Gly Gln Val Ile His→
 _____ AUTOTRANSLATION OF CO2 _____

1410 1420 1430 1440 1450 1460
 * * * * * *
 GAC TTC ACC CAG TGG TTC AAC GGC CCG ATG GAG TAC TAC CCG TCT ATC GGA CAG TTC CCC
 CTG AAG TGG GTC ACC AAG TTG CCG GCG TAC CTC ATG ATG GCG AAG TAG CCT GTC AAG GGG
 Asp Phe Thr Gln Trp Phe Asn Gly Arg Met Glu Tyr Tyr Arg Ser Ile Gly Gln Phe Pro→
 _____ AUTOTRANSLATION OF CO2 _____

1470 1480 1490 1500 1510 1520
 * * * * * *
 CTC AAC GGC CCC GTC GAA ATC CGT TGC TGC GGC CTC GAT CAA CCC TCG GAC GTC GAG GTC
 GAG TTG CCG GGG CAG CTT TAG GCA ACC ACC CCG GAG CTA GTT GGG AGC CTG CAG CTC CAG
 Leu Asn Gly Pro Val Glu Ile Arg Cys Cys Gly Leu Asp Gln Pro Ser Asp Val Glu Val→
 _____ AUTOTRANSLATION OF CO2 _____

1530 1540 1550 1560 1570 1580
 * * * * * *
 GAC TCG GCA GGC CCC CCC ACC ATC TCG GCC ATG CCG CCG CCG CCA GAC CAT CCG GAA TGG
 CTG AGC CGT CCG GGG GGG TGG TAG ACC CCG TAC GCG GCG GCG GGT CTG GTA GGC CTT ACC
 Asp Ser Ala Gly Pro Pro Thr Ile Ser Ala Met Arg Pro Arg Pro Asp His Pro Glu Trp→
 _____ AUTOTRANSLATION OF CO2 _____

1590 1600 1610 1620 1630 1640
 * * * * * *
 GAC ACC GCC ATC TGG CTC AAC GTC CTC GGC GTC CCC GGA ACC CCC GGC ATG TTC GCG TTC
 CTG TGG CCG TAG ACC GAG TTG CAG GAG CCG CAG GGG CCT TGG GGG CCG TAC AAG CCG AAG
 Asp Thr Ala Ile Trp Leu Asn Val Leu Gly Val Pro Gly Thr Pro Gly Met Phe Ala Phe→
 _____ AUTOTRANSLATION OF CO2 _____

FIG. 2.4

1650	1660	1670	1680	1690	1700
TAC CGC GAA ATG GAA CAG TGG ATG CCT AAT CAC TAC AAC AAC AAC GAC GCC ACC TTC CGC					
ATG GCG CTT TAC CTT GTC ACC TAC GGA TTA GTG ATG TTG TTG TTG CTG CGG TGG AAG GCG					
Tyr Arg Glu Met Glu Gln Trp Met Pro Asn His Tyr Asn Asn Asn Asp Ala Thr Phe Arg→					
AUTOTRANSULATION OF CO2 →					

1710	1720	1730	1740	1750	1760
CCA GAA TGG TCC AAG GGC TGG CGT TCG GCC CCG ACA AGC CGT ACA CCG ACG CCC CGA TCA					
GGT CTT ACC AAG TTC CCG ACC GCA AGC CGG GGC TGT TCG GCA TGT GGC TGC GGG GCT AGT					
Pro Glu Trp Ser Lys Glu Trp Arg Ser Ala Pro Thr Ser Arg Thr Pro Thr Pro Arg Ser→					
AUTOTRANSULATION OF CO2 →					

1770	1780	1790	1800	1810	1820
TCA CCC AAG GCC TCC CGC AGA CCT ACC GCG ACG GCG TCC CAT CGA GCG ACA ACT GGG ACA					
AGT GGG TCC CGG AAG GCG TCT GGA TGG CGC TGC CGC AAG GTA GCT CGC TGT TGA CCC TGT					
Ser Pro Arg Ala Ser Arg Arg Pro Thr Ala Thr Ala Ser His Arg Ala Thr Thr Gly Thr→					
AUTOTRANSULATION OF CO2 →					

1830	1840	1850	1860	1870	1880
CCG CCA ACG CCG CAT ACA ACG CGT TGG ATC CGC ACA AAG TCT TCA GCA ACA CCT TCC TGG					
GGC CGT TGC GGC GTA TGT TGC GCA AGC TAG GCG TGT TCC AGA AGT CGT TGT GGA AAG ACC					
Pro Pro Thr Pro His Thr Thr Arg Trp Ile Arg Thr Arg Ser Ser Ala Thr Pro Ser Trp→					
AUTOTRANSULATION OF CO2 →					

1890	1900	1910	1920	1930	1940
ACC AGT TGC TGC CCT GAG GTC CAA GCA CCA GGC ACG CAC TCT GCC AAC TCG ACG GTC GTC					
TGG TCA ACG ACG GGA CTC CAG GTT CGT GGT CCG TGC GTG AGA CCG TTG AGC TGC CAG CAG					
Thr Ser Cys Cys Pro Glu Val Gln Ala Pro Gly Thr His Ser Ala Asn Ser Thr Val Val→					
AUTOTRANSULATION OF CO2 →					

1950	1960	1970	1980	1990	2000
GCC ACT CCC CTA CTT TCG GGA GTG CCG CCG CCG TCG TGC GTT GCA GTG ACG GGG ATG AAG					
CGG TGA GGG GAT GAA ACG CCT CAC GCC GGC GGC ACG ACG CAA CGT CAC TCG CCC TAC TTC					
Ala Thr Pro Leu Leu Ser Gly Val Arg Pro Pro Ser Cys Val Ala Val Ser Gly Met Lys→					
AUTOTRANSULATION OF CO2 →					

2010	2020	2030	2040	2050	2060	2070
GAG TCC CCC CGC ATC CCG ACC AAG TAA C TGACTCAATC GCATCAGGA TGGATCGCCT CGTGCTACT						
CTC AAG GGG GCG TAG GGC TGG TCC ATT G ACTGAGTTAG CGCTATCTCT ACCTAGCGGA GCACGTATGA						
Glu Ser Pro Arg Ile Pro Thr Arg End→						
AUTOTRANSULATION OF CO2 →						

FIG. 2.5

2080	2090	2100	2110	2120	2130	2140
* * *	* * *	* * *	* * *	* * *	* * *	* * *
TTCCACGGCC	CTGGCATGAG	TTGAGAGCTC	GGACCGAGCC	GACCGAATCG	TGGCGCTGTC	GCTGCGCGCC
AGGTGCCGG	GACCGTACTC	AACTCTCGAG	CCTGGCTCGG	CTGGCTTAGC	ACCGCGACAG	CGACGCGCGG
2150	2160	2170	2180	2190	2200	2210
* * *	* * *	* * *	* * *	* * *	* * *	* * *
CCCGGCTCGG	ACGACGACGA	GTCTCTCCG	GGGTTGAGCG	CGCCACCGAGC	GGGATGCTCG	GAGGAGCCGG
GGGCGGAGCC	TGCTGCTGCT	CAGGAGAGGC	CCCAAGCTGC	GCGGTGGTCG	CCCTACGAGC	CTCTCGGCC
2220	2230	2240	2250	2260	2270	2280
* * *	* * *	* * *	* * *	* * *	* * *	* * *
TGCGCTCTTC	CCTCTCCGCG	CGGCGCGCGA	ACACCGACTC	GGACTTCGGG	GTATTTCCGA	TCGGAGCATT
ACGCGAGAG	GGAGAGGGCG	GCCCGCGCGT	TGTTGCTGAG	CCTGAGGCC	CATAAGCGT	AGCTCGTAA
2290	2300	2310	2320	2330		
* * *	* * *	* * *	* * *	* * *		
GTCCAGATT	CATCTCCCAT	GACTCACATG	GAGCGCTCTC	ACCCCGGTG	ACCAGGCC	
CAGGGTCTAA	GTAGAGGGTA	CTGAGTGATC	CTCGCGAGAG	TGGGGGCCAC	TGGTCCGG	

FIG. 2.6

INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): C12Q 1/60; C12Q 1/44; C12Q 1/26; C12N 15/09; C12N 9/02;
C12N 1/21; U.S.C1.: 435/11, 19, 25, 28, 172.3, 189, 252.3, 320

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷

Classification System	Classification Symbols
U.S.	435/ 11, 19, 25, 28, 172.3, 189, 252.3, 320 935/ 9, 22, 60, 72

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are included in the Fields Searched ⁸

Chemical Abstract Database (CA): 1967-1990; Biosis Database 1969-1990; Keywords: cholesterol oxidase, Rhodococcus, Streptomyces, vector, plasmid, gene

III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	JOURNAL OF BACTERIOLOGY; Volume 170, issued 1988, February, (M.E. VOGT SINGER), "Construct-	I and 12
Y	ion of an Escherichia coli-Rhodococcus shuttle vector and plasmid transformation in Rhodococcus spp.", See pages 638-645	2-11, 13-28 and 33-43
Y	APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Volume 32, issued 1986, December, (Y. MUROOKA), "Cloning and expression of a Streptomyces cholesterol oxidase gene in Streptomyces lividans with plasmid pIJ702", See pages 1382-1385	1-48
Y	U.S., A., 4,409,326, (I.E. MODROVICH), 11 October 1983, See columns 5-6	29-32

* Special categories of cited documents: ¹⁴

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Z" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

6 FEBRUARY 1990

Date of Mailing of this International Search Report

21 FEB 1990

International Searching Authority

ISA/US

Signature of Authorized Officer

RICHARD C. PEET

Richard C. Peet